THE COMPARATIVE TOXICITY OF CRUDE AND REFINED OILS TO *DAPHNIA MAGNA* AND *ARTEMIA*

by

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EE-111 January, 1989

ABSTRACT

Acute toxicity tests were performed on the water soluble fractions (WSF)s of 22 oils, eight pure hydrocarbons and two reference toxicants using Daphnia magna in freshwater and Artemia in seawater. The oils tested were frequently or potentially transported in Canada. Test concentrations were confirmed by fluorescence spectroscopy. The exposure responses range from a 48 hour EC50 of 1.3% of the WSF, to those for which the oils were neither lethal nor immobilized the animals at 100% concentration. Generally, Daphnia magna appeared slightly more sensitive than Artemia. Two different modes of toxic action were identified for the oils tested. Toxicity results are summarized by ranking the oils from most to least toxic. The toxicity of the pure hydrocarbons was similar to that found in the literature.

RÉSUMÉ

Des essais de toxicité aigë ont été effectués sur des fractions solubles dans l'eau (FSE) de 22 huiles, huit hydrocarbures purs et deux substances toxiques de référence pour déterminer leur effet sur Daphnia magna dans l'eau douce et Artemia dans l'eau de mer. Les huiles analysées ont souvent été ou seront éventuellement transportées au Canada. Les concentrations expérimentales ont été confirmées par spectroscopie de fluorescence. Les réactions à l'exposition vont de celles correspondant à une TE50 de 48 heures de 1,3 % des FSE à celles pour lesquelles les huiles ne causaient ni d'effet létal ni d'immobilisation des animaux à une concentration de 100 %. Dans l'ensemble, Daphnia magna semblait légèrement plus sensible que Artemia. Deux différents modes d'action toxique ont été mis en évidence pour les huiles analysées. Les résultats de toxicité sont résumés par ordre décroissant de toxicité des huiles. La toxicité des hydrocarbures purs était semblable à celle établie dans la documentation spécialisée.

ACKNOWLEDGEMENTS

This study was financed by the Environmental Emergencies Technology Division (EETD), Conservation and Protection, Environment Canada.

G. Sergy, A. Bobra, P. Wells, R. Percy and K. Doe drew up the terms of reference for this study.

The authors would like to thank A. Bobra and M. Fingas (EETD, Environment Canada, Ottawa) and Esso Petroleum Canada for supplying the test oils.

Finally, we would like to thank Dr. H.S. Samant and Dr. P.G. Wells for reviewing the manuscript for their many helpful comments, and Ms. Z. Babin and Ms. G. Babin for typing the final versions of the report.

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1. INTRODUCTION

A study to measure the acute toxicity of petroleum products to Daphnia magna and Artemia commenced in September, 1986. The study was conducted at the Environmental Protection Atlantic Region bioassay facilities located at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. In total, 22 oils (crudes, fuels, lubes and bunker), eight aromatic hydrocarbons, and two reference toxicants were tested. The oils selected for testing were frequently (or could be potentially) transported in Canada. Comparative toxicity data on these oils was considered a useful addition to Environment Canada's Environmental Emergency Technology Division "Catalogue of oil properties" (Report EE-77; March, 1986). This information was considered as being useful to Regional Environmental Emergency Coordinators during spill situations and as an aid in prosecutions.

This report summarizes the methods used in measuring the acute toxicity of petroleum products and the results obtained. It should be noted that this report is not intended as an exhaustive analysis and interpretation of the test results, but merely as a data report summarizing procedures and results to satisfy the terms of the contract. In a companion study, water soluble fractions of oils used in this study were analysed by purge and trap GC for individual petroleum hydrocarbons (Suntio et al. 1986).

It is planned to further analyse the results from both studies with regard to sources of toxicity in water soluble fractions of petroleum products using a model for joint hydrocarbon toxicity. These results will be published elsewhere.

2. METHODS AND MATERIALS

Acute toxicity tests were performed on the water soluble fractions (WSF) of 22 oils, eight pure hydrocarbons and two reference toxicants using Daphnia magna in freshwater and Artemia in seawater. For Daphnia magna the dilution water was a reconstituted fresh water using the formulation outlined in the International Standard ISO-6341-1982(E) (Appendix 1). For Artemia, the dilution water was prepared using a synthetic seawater from "Instant Ocean" sea salt at 30 0/00 ± 2 0/00 (Appendix 1.)

The same dilution water was used to culture and hold the animals, prepare WSFs and conduct the toxicity tests for each crustacean.

Exposures for the toxicity tests were conducted for 48 hours with emphasis on the initial onset of toxic effects (first 4 hours). The following sections present in detail the methods used in these toxicity tests.

2.1 Preparation of Water Soluble Fractions (WSFs)

The WSFs were prepared using a ratio of reconstituted fresh (or salt) water to oil of 40:1 by volume. The WSFs were prepared in Erlenmeyer flasks (1000 mL for Artemia and 2000 mL for Daphnia magna) fitted with a teflon stopcock near the bottom for drainage. The caps were lined with 2 inch teflon tape. The flask was then covered with aluminium foil to minimize photodegradation of the oil. The water and a teflon coated magnetic stirring bar were added to the flask. The oil was gently added to the water down the side of the flask to form an oil layer about 1/4" - 1/2" thick. The Erlenmeyer flask was then tightly capped and the WSF was stirred for 3 days on the lowest speed (about 1 revolution per second) so that there was no vortex on the underside of the oil and no oil emulsification occurred. Water soluble fractions with overlying excess whole oil were stored tightly capped in the dark, after preparation for up to five days before use in the toxicity tests.

2.2 Artemia Bioassays

Dried Artemia cysts were received from the Laboratory for Biological Research in Aquatic Pollution, Artemia Reference Centre, State University of Ghent, Belgium on 14 November 1986. They were stored in a dessicator until needed. The cysts were identified as batch A.F. 845/1, and were reported to be of comparable sensitivity as batch RAC cysts to the reference toxicant DSS.

2.2.1. Hatching and Holding of nauplii

Approximately 0.1 grams of cysts were used for each test series. The cysts were incubated in 100 mL Instant Ocean synthetic seawater in a 100 mL graduated cylinder. The temperature was kept at 25-27^{0}C for 24-27 hours. Lateral illumination from an incandescent light bulb (60 watts), 20-25 cm from the hatching device provided the light and heat source. All cysts and hatching nauplii were kept in constant suspension by gentle aeration provided by a disposable pipette delivering air near the bottom of the cylinder.

At the end of the hatching period the nauplii were at the instar I stage. These nauplii were then transferred using a disposable Pasteur pipette (tip opening 1 mm) into a beaker containing 300 mL of seawater. The beaker was incubated in the dark at 20^{0}C $\pm$ 2^{0}C for 24 hours. This holding time ensures that all organisms have moulted to the instar II stage and sometimes instar III stage. These organisms were transferred to a plastic petri dish (100 mm diameter) for further distribution to test vials.

2.2.2. Artemia Toxicity Tests

Instar II (and a small proportion of instar III stage) Artemia were used as the test organisms for the toxicity tests. Test chambers were 30 mL glass vials with teflon-lined screw-on caps. Empty and full vials

were weighed in order to calculate the proper dilutions. Ten nauplii were transferred with a Pasteur pipette into a known weight of dilution water in each pre-weighed vial. Additional amounts of dilution water were then added if needed in order to reach the desired weight. When all the vials were filled with dilution water plus organisms, the vials were topped up to overflow with the WSF. For test solutions composed of 100% WSF, a small amount of the WSF was added to the vials first. Then the organisms were added and topped up with the WSF. The WSF for all cases was dispensed directly from the Erlenmeyer flask, and the vials were capped immediately with no air space. The vials were inverted gently by hand 5 times. The final weight of the full vial was taken to calculate the actual concentrations as a percentage of the WSF. The vials were place in an incubator. Tests were conducted in the dark at a temperature of approximately 20^{0}C. Test duration was 48 hours (Note: 5 oils, toluene and p-xylene were tested for 24 hours duration before it was requested that tests be extended to 48 hours).

Vials were removed from the incubator and observations were made at 0.5 hour, 4 hours, 24 hours and 48 hours for mobility with the naked eye and using a Zeiss stereomicroscope (X50 magnification). Mobility was defined as swimming animals, either actively swimming or at least occasionally moving their bodies off the bottom to swim. Immobility included all animals not swimming (which could include those lying on the bottom but moving appendages or those showing no signs of movement in a period of 10 seconds, and included dead animals).

At test termination (usually 48 hours) the test observations were made for mobile, immobile but alive, and dead animals. Animals were transferred out of the test solutions to a watch glass and death was defined as a lack of all movement when individuals were observed closely under the stereomicroscope (X50 magnification) for 10 seconds.

Initially, and at test termination, selected test solutions were analysed for petroleum hydrocarbons using the methods described in Section

2.4. Test solutions were also measured for temperature, dissolved oxygen and pH at the start of the tests. These results are shown in Appendix 2.

If organism mortality or immobility occurred in greater than 10% of the control test organisms, the test was invalidated and repeated. The invalidated test data are not included in this report. Some tests were also repeated when toxicity data did not show a clear dose - response relationship (i.e. a higher concentration never kills a lower percentage of test organisms than a lower concentration). All raw response data are available upon request.*

The response data was used to calculate EC50** and/or LC50*** data at 4 $\pm$ 0.25; 24 $\pm$ 2 and 48 $\pm$ 2 hours exposure as described in Section 2.5.

2.3 Daphnid Bioassays

Neonates of Daphnia magna were used in all Daphnia toxicity tests. These animals were obtained from cultures maintained by the Aquatic Toxicity Section of EP, Atlantic Region in Dartmouth, N.S.

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* Available from Environmental Emergency Technology Division, Environment Canada, River Road Environmental Technology Centre, Ottawa, Ontario, K1A 1C8.

** Calculated concentration that causes 50% of test organisms to stop swimming (= "immobile", includes immobile and dead animals) at the specified exposure time.

*** Calculated concentration that causes 50% mortality of the test organisms at the specified exposure time (only dead animals included).

2.3.1 Culture of Test Animals

The original cultures of Daphnia magna were received from EPS Quebec Region in 1982. Animals were cultured in ISO6341 synthetic hard water (Appendix 1) and fed with living cells of Chlorella vulgaris (strain 259 or 260 from the University of Texas at Austin, Texas), supplemented with a suspension of Tetramin^{R} fish food. The feeding rates have been described in a draft test protocol (Cabridenc 1985). Animals are fed and culture solutions renewed three times a week. The age of each parental generation was strictly controlled (between 2 and 4 weeks old), and young from the second or subsequent broods, always less than 24 hours old, were used to start the next generation. The Daphnia magna are normally cultured individually in 50 mL of culture water. Occasionally, when large numbers of young are required for toxicity tests, 15 animals were cultured in 750 mL of culture water (50 mL per animal) under the same conditions described above.

2.3.2 Daphnid Toxicity Tests

Neonates less than or equal to 24 hours old from the second or subsequent brood of animals approximately 3 weeks ($\pm$ 1 week) old, were used in all toxicity tests on Daphnia magna. Test chambers were 120 mL glass bottles with teflon-lined caps. Empty and full bottles were weighed in order to calculate the proper dilutions. 10 neonates were transferred using a pasteur pipette into a known weight of dilution water in each pre-weighed bottle. Additional amounts of dilution water were then added if needed in order to reach the desired weight. When all the bottles were filled with water plus organisms, the bottles were topped up to overflow with the WSF. For test solutions composed of 100% WSF, a small amount of the WSF was added to the vials first. Then the organisms were added and topped up with WSF. This WSF for all cases was dispensed directly from the Erlenmeyer flask, and the bottles were capped immediately with no air space. The bottles were inverted gently by hand 5 times. The final weight of the full bottle was taken to calculate the actual concentration as a percentage of the WSF.

The bottles were placed in an incubator. The photoperiod of 16 hours Light and 8 hours Dark was provided by fluorescent light. Temperature was approximately 20^0C. Test duration was 48 hours. Bottles were removed from the incubator and observations were made at 0.5 hour, 4 hour, and 24 hours for mobility. Mobility was defined as swimming animals, either actively swimming or attempting to swim. Immobility included all animals showing no signs of swimming within 15 seconds of gentle agitation, and included dead animals.

At test termination (48 hours) observations were made for both mobility and death. Animals were transferred out of the test bottles to a watch glass and death was defined as a lack of movement of antennae and lack of heartbeat when observed under a Zeiss stereomicroscope for 10 seconds (X50 mganification).

Measurements were made for temperature, dissolved oxygen and pH at the start and termination of the test. These measurements are summarized in Appendix 2.

In addition, initially, and at test termination selected test solutions were analysed for petroleum hydrocarbons using the methods described in Section 2.4.

If organism or mortality or immobility occurred in greater than 10% of the control test organisms, the test was invalidated and repeated. The invalidated test data are not included in this report. Some tests were also repeated if a clear dose - response relationship was not demonstrated. These latter tests were not invalidated, but are available together with the other raw response data on request.*

The response data was used to calculate EC50 and/or LC50 values** after 4 $\pm$ 0.25; 24 $\pm$ 2 and 48 $\pm$ 2 hours exposure as described in Section 2.5.

* Address given in Section 2.2.2

** EC50 and LC50 defined in Section 2.2.2

2.4 Analysis of Test Solutions for Petroleum Hydrocarbons

Initially, and at test termination, selected test solutions were measured for petroleum hydrocarbons by fluorescence spectroscopy. Fluorescence spectroscopy was chosen as it is a simple screening technique and has been found suitable in estimating total petroleum hydrocarbon concentrations (e.g. Zitko and Carson 1970; Keizer and Gordon 1973). Extra bottles containing the test solutions were made up for chemical analysis. These were made up using the same dilution water and WSFs as for the toxicity tests and capped in the same manner but no test animals were added. For the initial samples, the solutions were extracted immediately, while the termination samples were placed in the incubator along with the toxicity tests and extracted at test termination.

The test solutions analysed for hydrocarbons in the Daphnid tests were 100%, 32%, 10%, 0% (control test), while the test solutions analysed for hydrocarbons in the Artemia tests were 100% and 0% (control test). Extractions were performed using 20 mL aliquots of hexane. The test solutions were placed in 250 mL separatory funnels, 20 mL of hexane were added and shaken vigourously for 1 minute. When the two layers separated (10 to 30 minutes), the water layer was drained into the original test container, and the hexane layer was drained into a volumetric flask. The extraction process was repeated and the combined hexane extracts made up to either 50 or 100 mL with hexane. These extracts were stored in a cooler at $4^{0}C$ until analyzed.

The extracts of the test solutions were measured on a Perkin Elmer MPF-3 Fluorescence Spectrophotometer. The fluorescence intensity of the test solution extracts were compared to a calibration curve for each test material. Calibration curves were prepared by analysing varying concentrations of each test material made up with hexane.

The amount of each test material in the extracted samples were calculated on a weight to volume basis and back-calculated to concentrations in the original test solutions.

For each test material both the standard solutions prepared for calibration curves and the extracts of the water soluble fractions were scanned to determine the optimum excitation and emission wavelenghts. The wavelengths selected, and a summary of levels of hydrocarbons in all test solutions measured are presented in Appendix 3.

2.5 Calculation of EC50s and LC50s

Acute lethal toxicity was expressed either as EC50s or LC50s along with 95% confidence limits at various time periods. EC50s were calculated for 4 and 48 hours exposure. LC50s were calculated only at 48 hours. Nominal values for EC50s and LC50s were derived by probit analyses using the BMD03S program (Dixon 1973) where two or more partial responses occurred. Where there are fewer than two partial responses, the EC50s and LC50s were calculated using the binomial test (Stephan 1977), using the "Lethal" computer program. Occasionally, the data did not show a clear dose-response relationship and in these cases estimates of the EC50s and the LC50 were derived using the graphical method of Litchfield and Wilcoxon (1949), or were reported as not calculable if the data were uninterpretable.

The nominal EC50/LC50 values were expressed as a percentage of the WSF. To obtain estimates of EC50/LC50 based on initial measured test concentration, the nominal value was multipled by the initial concentration in the 100% WSF as measured by Fluorescence (Section 2.4) or by purge and trap GC (Suntio et al. 1986).

2.6 QA/QC Tests

Reference toxicants were used for both species in order to test the sensitivity of our test organisms against reported reference toxicant values. For Artemia, methods used were as reported in Section 2.2, and the reference toxicants were dodecyl sodium sulphate (DSS) and potassium dichromate. The reference toxicant for the Daphnid tests was potassium

dichromate. Methods used to test this material were as described in Anonymous (1982), to facilitate comparison with this published information. Methods differ from those used to test water soluble fractions of oils reported in Section 2.3. Briefly, reference toxicant tests for Daphnia magna were conducted in uncapped glass vials using 20 neonates in 100 mL of test solution. Test animals were not fed during the test. Tests were conducted at 20°C in the dark, and the response measured was the 24 hour EC50 for immobilization.

As a further check on the quality of the data, all tests were replicated, with up to six replicate tests being conducted for each organism-toxicant combination.

3. RESULTS AND DISCUSSION

The results of the study are presented in Tables 1 to 6 as 4 hour EC50s, 48 hour EC50s, and 48 hour LC50s for both Artemia and Daphnia magna. The data have been presented as nominal LC50s and EC50s (as % of WSF), as LC50s and EC50s based on measured levels (by fluorescence, in mg/L), and, where the data was available, as LC50s and EC50s based on measured levels by purge and trap GC in mg/L (chemical measurements from Suntio et al. 1986). All valid tests are shown in the tables, in some cases as many as four replicates. In almost every case, 95% confidence limits for the replicated tests overlapped, and so the replicated test results were not significantly different. The only exception occurred with 48 hour LC50 values for leaded gasoline to Daphnia magna (4 replicates, Table 6), in which the confidence limits for one replicate did not overlap that of one of the other replicates. Taken as a whole, these four values are similar (range of 48 hour LC50 values 4.5-15.1). The results in Tables 1-3 for Artemia range from a 48 hour EC50 4.3% of the WSF for new auto lube oil to several oils which were neither lethal to nor immobilized the animals at 100% WSF. The results in Tables 4-6 for Daphnia magna range from a 48 hour EC50 of 1.3% of the WSF for unleaded gasoline to oils that were completely non lethal at 100% WSF. Note, however, that all oils did cause some immobility to the Daphnia magna by 48 hours (Table 5), indicating the Daphnia magna in freshwater to be somewhat more sensitive than Artemia in seawater. The data from all the replicates shown in Tables 1 to 6 were combined to produce a single value (EC50 and LC50) for each species - oil combination. These data are presented in Tables 7 and 8.

The results in Tables 1-8 can be conveniently summarized by ranking the oils from most toxic (rank = 1) to least toxic (highest rank number). This is shown in Tables 9(a), 9(b), 10(a) and 10(b). Two methods of presentation are given for the convenience of the reader. There are many "ties" in Tables 9 and 10, which rank the 4 and 48 hour EC50s, and the 48 hour LC50s for the various oils based on nominal values as % of WSF. Values of greater than 100% are given a tie at the highest rank (lowest

toxicity). It should be noted that the ranking of the oils may have been different if measured values had been used. Further investigation of this is planned in the near future. In general, the WSF of the gasolines, condensates, furnace fuel and diesel oil turned out to be the most acutely toxic, while the WSF of bunker C - light, heavy marine lube and some of the crude oils such as Tarsuit, Lago Medio, Atkinson, Bent Horn and Amauligak were the least acutely toxic to both species of test animals.

Oils which contain a large concentration of low boiling-point hydrocarbons (e.g. gasolines, condensates, furnace, diesel and some crudes) acted on the organisms very rapidly as evidenced by their toxicity ranking for the 4 hour EC50 values. By comparison, the new and the used auto lube oils showed no toxic effects at four hours but marked toxicity by 48 hours. This suggests a different mode of action for these oils. Preliminary results suggest that heavy metals from the lube oils are the cause of the observed lethality (as opposed to toxicity caused by hydrocarbons from most of the other oils tested). This data will be published at a later date as testing of WSFs for heavy metals is incomplete at the time of writing of this report.

Several pure hydrocarbons were also tested during this study. This was done to aid in the interpretation of causes of toxicity of the oil WSFs, as well as to aid in comparison of the results of this study with the results from other studies which included these test materials (see, in particular: Abernethy et al 1986). Tables 11 and 12 summarize the toxicity of the pure hydrocarbons to the two test species showing each replicate, while Tables 13 and 14 show the results combined into one value (EC50 and LC50) for each species-oil combination. All replicates are shown, and in almost every case there is excellent agreement between the replicates. The only exception is for benzene tested with Daphnia magna (six replicates), where the 95% confidence limits for one of the 48 hour LC50 values does not overlap with the limits for two of the other 48 hour LC50 replicates. Taken as a whole, however, these six replicates are similar (range of 48 hour LC50 values 3.8-10.0). Based on measured concentrations, cumene and

naphthalene are the most toxic compounds to Artemia. Another way to look at the toxicity of a compound is to consider its potency, i.e. the number of times a saturated solution can be diluted and still result in a toxic solution. Based on this perspective, benzene would be the most toxic compound to Artemia as its nominal LC50 as percentage of WSF is the lowest. Similarly for Daphnia magna, naphthalene and o-xylene are the most toxic compounds based on measured values, while benzene would be the most toxic from a potency point of view. It should be stated that the values for Artemia in Tables 11 and 13 are very similar to those presented in Abernethy et al (1986). The values for Daphnia magna (Tables 12 and 14) are similar only if we compare our 48 h EC50s with the 48 h LC50s from Abernethy et al (1986). Our LC50 values are far higher (up to an order of magnitude or greater). The difference results from different definitions of death used in the two studies. Abernethy et al (1986) state "Each animal was classified as alive/swimming or dead." By this definition, and that in Bobra et al 1983, our EC50 for immobilization corresponds to their LC50. When this is taken into account, the only major difference between this study and that of Abernethy et al (1986) when comparing our EC50s with their LC50s, is with their LC50 value for Daphnia magna with cumene, which is about an order of magnitude lower than our measured 48 h EC50 value. This difference cannot be explained at this time, but could be due to an impurity in the cumene (different source, different batch, etc.), slight differences in test methodology, etc.

Table 15 shows the results of some tests with Daphnia magna using Lago Medio as the model test toxicant. In these tests, feeding, light regime, and air head-space and capping of the test containers were varied from the standard test (which is described in Section 2.3.2). As can be seen from the table, the only variables which made an appreciable difference in the test result were when either a large head space was left in the test container or when the test containers were left uncapped.

Appendix 2 summarizes results of temperature, dissolved oxygen and pH measurements conducted on the freshwater and saltwater toxicity test

solutions. All temperature and pH measurements were within acceptable limits, as were all but one of the dissolved oxygen measurements. The only exception was for Bunker C - light oil which depressed dissolved oxygen levels in the 100% salt water WSF test solution to 1.5 mg/L. However, since the 100% WSF was non-lethal to Artemia and caused little immobility it appears that even this very low dissolved oxygen value was of minor consequence.

3.1 Quality Assurance/Quality Control (QA/QC) Test Results

To put the results of this study in perspective, reference toxicant tests were performed on both species as described in the Methods and Materials Section. The results of these tests for the reference toxicants dodecyl sodium sulphate (DSS) and potassium dichromate with Artemia are shown in Table 16. Three different batches of DSS were tested with markedly different results for the batch obtained from Fisher Scientific. The values for the Kodak batch (range of LC50 values 27.9-36.4 mg/L, N = 4) and the batch received from the University of Toronto (range of LC50 values 26.5-28.5 mg/L, N = 2) were within the range found during an intercalibration exercise conducted by the Artemia Research Centre (Persoone and Vanhaecke 1981). For potassium dichromate, the LC50 values were 134 mg/L (N = 2), again within the range of values reported by Personne and Vanhaecke (1981).

The results of toxicity tests for Daphnia magna with the reference toxicant potassium dichromate are presented in Table 17. Using the methods specified in Anonymous (1982) the 24 hour EC50 should fall within the range 0.9-2.0 mg/L. Of twenty tests conducted between August, 1986, and March 1987, only 3 values fell marginally outside of this range (the lowest value was 0.8 mg/l). From the results of these tests, it can be concluded that the test organisms used in this study were of acceptable sensitivity to these widely recognized reference toxicants.

In addition to the results of reference toxicant tests summarized above, all tests were replicated to demonstrate their repeatability (up to six replicates were conducted). As discussed in Section 3, replicated tests on one test material and one species gave values which were not statistically different in virtually every case.

4. CONCLUSIONS

(i) For Artemia, the most toxic oils were new automotive lube oil (mobility) and leaded gasoline (lethality).

(ii) Several oils showed no acutely toxic effects to Artemia. These oils were used automotive lube oil, Tarsuit crude, Atkinson crude, heavy marine lube oil and Bunker C-Light.

(iii) For Daphnia magna, the most toxic oils were unleaded gasoline (mobility) and furnace fuel oil (lethality).

(iv) Water soluble fractions of all oils affected the mobility of Daphnia magna. However, Lago Medio crude, Atkinson crude, heavy marine lube oil and Bunker C-Light were not acutely lethal to Daphnia magna.

(v) Daphnia magna appear to be more sensitive to water soluble fractions of petroleum oils than Artemia, though this may be partially attributed to the higher solubility of hydrocarbons in fresh water than salt water.

(vi) Benzene was the most potent of the hydrocarbons tested to both species (nominal concentration as % WSF). Naphthalene was the most toxic hydrocarbon to both species when expressed as measured concentrations by fluorescence spectroscopy.

5. RECOMMENDATIONS

It is recommended that oils frequently used or transported in Canada for which no toxicity data are available be tested using these same test species and methods to extend the data base on petroleum toxicity, and to allow a basis for comparison of their relative toxicity and environmental effects with other oils of known toxicity.

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Table 1.

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	36.4 (18-56) 42.3 (32-56)	18.5 (9.2-28.5) 21.5 (16.3-28.5)	
Leaded Gasoline	18.5 (7.9-29.1) 22.3 (10-32)	24.5 (10.5-38.5) 29.5 (13.2-42.4)	
Unleaded Gasoline	12.6 (10-18) 12.6 (10-18)	32.8 (26.1-47.0) 32.8 (26.1-47.0)	
Diesel	75.2 (45.4-104.9) >100	45.4 (27.4-63.4) > 60.4	
Sable Island Condensate	19.4 (10-32) 30.0 (20.4-39.6)	2.3 (1.2-3.8) 3.6 (2.4-4.7)	
Auto Lube (New)	> 100 > 100 > 100 > 100	> 1.12 > 1.12 > 1.7 > 1.7	
Auto Lube (Used)	> 100 > 100	>16.0 > 9.7	
Bent Horn	> 100 > 100	> 5.3 > 5.3	> 6.0 > 6.0
Venture Condensate	36.4 (18-56) 42.3 (32-56)	6.0 (3.0-9.2) 7.0 (5.3-9.2)	

Table 1. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Synthetic	98.6 (13.7-183.5)	5.3 (0.7-9.8)	
	78.8 (40.5-117.1)	4.2 (2.2-6.3)	
	98.8 (0.11-197.7)	4.5 (0.005-9.0)	
	>100	> 4.6	
Western Sweet Blend	70.3 (56-100)	9.6 (7.7-13.7)	15.5(12.3-22.0)
	75.0 (56-100)	10.3 (7.7-13.7)	16.5(12.3-22.0)
Transmountain	74.8 (56-100)	4.2 (3.1-5.6)	
	>100	> 5.6	
Norman Wells	71.5 (31.7-111.4)	6.2 (2.8-9.7)	7.2 (3.2-11.1)
	79.1 (56-100)	6.9 (4.9-8.7)	7.9 (5.6-10.0)
Hibernia	>100	>10.6	> 18.7
	100	10.6	18.7
Amauligak	>100	> 6.5	
	>100	> 6.5	
Prudhoe Bay	>100	> 8.6	> 20.5
	>100	> 8.6	> 20.5
Tarsuit	>100	> 7.2	
	>100	> 7.2	
Venezuelan BCF-22	74.8 (56-100)	7.17 (5.4-9.6)	
	74.8 (56-100)	7.17 (5.4-9.6)	

Table 1 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Artemia: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Heavy Marine Lube	>100 >100	>1.8 >1.6	
Lago Medio	>100 >100	>9.8 >9.8	
Atkinson	>100 >100	>2.0 >2.0	
Bunker C. Light	>100 >100	>2.3 >2.3	

Table 2.

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	17.2 (7.9-26.6) 15.7 (8.6-22.7)	8.8 (4.0-13.5) 8.0 (4.4-11.6)	
Leaded Gasoline	13.2 (7.9-18.5) 16.5 (7.3-25.8)	17.5 (10.5-24.5) 21.8 (9.7-34.1)	
Unleaded Gasoline	9.5 (6.5-12.5) 12.0 (<18)	24.8 (17.0-32.6) 31.1 (<47.0)	
Diesel	34.5 (25.4-43.5) 37.2 (26.9-47.6)	20.8 (15.3-26.3) 22.5 (16.3-28.8)	
Sable Island Condensate	17.3 (5.3-29.3) 15.0 (3.1-26.9)	2.1 (0.6-3.5) 1.8 (0.4-3.2)	
Auto Lube (New)	6.3 (0.7-12.0) 4.3 (0-11.9)	0.11 (0.01-0.21) 0.07 (0-0.21)	
Auto Lube (Used)	80.9 (7.0-154.8) 78.6 (7.6-149.7) 96 (0-203.3) > 100	12.9 (1.1-24.7) 12.6 (1.2-23.9) 9.3 (0-19.7) > 9.7	
Bent Horn	61.8 (20.7-102.9) > 100	3.3 (1.1-5.5) > 5.3	3.7 (1.2-6.2) > 6.0
Venture Condensate	19.9 (15.3-24.5) 24 (18-32)	3.3 (2.5-4.0) 3.9 (3.0-5.3)	

Table 2. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Artemia: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Synthetic	68.7 (18-100) 32.7 (24-41.5) 27.1 (6.9-47.3) 30.3 (20.3-40.3)	2.4 (0.6-3.5) 1.2 (0.8-1.5) 1.2 (0.3-2.2) 1.4 (0.9-1.8)	
Western Sweet* Blend	67.1 (32-100) 55.2 (35.7-74.7)	9.2 (4.4-13.7) 7.5 (4.9-10.2)	14.8 (7.0-22) 12.1 (7.9-16.4)
Transmountain*	70.4 (56-100) 61.5 (37.1-86)	3.9 (3.1-5.6) 3.4 (2.1-4.8)	
Norman Wells	63.8 (<100) 67.1 (<100)	5.6 (<8.7) 5.8 (<8.7)	6.4 (<10.0) 6.7 (<10.0)
Hibernia	70.4 (10-100) 52.5 (26.7-78.3) 62.1 (35.8-88.3) 74.7 (56-100)	7.5 (1.1-10.6) 5.6 (2.8-8.3) 6.6 (3.8-9.4) 7.9 (6.0-10.6)	13.2 (1.9-18.7) 9.8 (5.0-14.6) 11.6 (0.7-16.5) 14.0 (1.1-18.7)
Amauligak *	87.6 (>56) >100	5.7 (>3.7) >6.5	
Prudhoe Bay	42.1 (19.7-64.5) 37.1 (18.5-55.6)	3.6 (1.7-5.5) 3.2 (1.6-4.8)	8.6 (0.3-1.1) 7.6 (0.3-1.0)
Tarsuit *	>100 100	>7.2 7.2	
Venezuelan BCF-22	42.3 (32-56) 42.3 (32-100)	4.1 (3.1-5.4) 4.1 (3.1-9.6)	

Table 2 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Artemia: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Heavy Marine Lube	>100 >100	>1.8 >1.6	
Lago Medio	>100 >100	>9.8 >9.8	
Atkinson*	95.8 (>56) >100	1.9 (>1.1) >2.0	
Bunker C. Light	91.1 (>56) >100	2.1 (>1.3) >2.2	

* 24 hour data, not 48 hours.

Table 3.

Acute toxicity of water soluble fractions of crude and refined oils to Artemia: 48 hour LC50. 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	21.7 (14.3-29.1) 22.2 (14.6-29.7)	11.0 (7.3-14.8) 11.3 (7.4-15.1)	
Leaded Gasoline	16.6 (7.3-25.8) 16.1 (8.2-23.9)	22.0 (9.7-34.1) 21.3 (10.9-31.6)	
Unleaded Gasoline	22.6 (18-32) 22.6 (<32)	59.0 (47.0-83.5) 59.0 (<83.5)	
Diesel	41.4 (26.9-55.8) 37.2 (26.9-47.6)	25.0 (16.3-33.7) 22.5 (16.3-28.8)	
Sable Island Condensate	22.1 (16.1-28.1) 21.5 (15.2-27.7)	2.6 (1.9-3.4) 2.6 (1.8-3.3)	
Auto Lube (New)	53.9 (0-471.9) 28.8 (12.2-45.3) 79.3 (0-179.9)	0.6 (0-5.3) 0.5 (0.2-0.8) 1.4 (0-3.1)	
Auto Lube (Used)	>100 >100	>16.0 > 9.7	
Bent Horn	>100 >100	> 5.3 > 5.3	>6.0 >5.0
Venture Condensate	24.9 (16.5-33.4) 27.6 (20.1-35.1)	4.1 (2.7-5.5) 4.5 (3.3-5.8)	

Table 3. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*: 48 hour LC50. 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Synthetic	68.7 (18-100) 37.4 (25.4-49.5) 33.5 (15.8-51.2) 43.4 (27.0-59.8)	3.7 (1.0-5.4) 2.0 (1.4-2.6) 1.5 (0.7-2.3) 2.0 (1.2-2.7)	
Western Sweet * Blend	70.3 (56-100) 86.4 (0.11-172.8)	9.6 (7.6-13.7) 11.8 (0.01-23.6)	15.5 (12.3-22.0) 19.0 (0.02-38.0)
Transmountain *	>100 >100	>5.6 >5.6	
Norman Wells	63.4 (23.5-103.3) 64.3 (20.1-108.5)	5.5 (2.1-9.0) 5.6 (1.8-9.5)	6.3 (2.4-10.3) 6.4 (2.0-10.9)
Hibernia	65.7 (18.4-113.00) 56.8 (25.8-87.7) 87.5 (>56) 75.5 (50.4-108.7)	7.0 (2.0-12.0) 6.0 (2.7-9.3) 9.3 (>6.0) 8.0 (5.4-11.6)	12.3 (3.4-21.1) 10.6 (4.8-16.4) 16.4 (>10.5) 14.1 (9.4-20.3)
Amauligak *	>100 >100	>6.5 >6.5	
Prudhoe Bay	50.6 (26.6-74.7) 69.5 (1.5-137.4)	4.3 (2.3-6.4) 6.0 (0.1-11.8)	
Tarsuit *	>100 >100	>7.2 >7.2	
Venezuelan BCF-22	42.3 (32-56) 42.3 (32-56)	4.1 (3.1-5.4) 4.1 (3.1-5.4)	

Table 3 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*: 48 hour LC50. 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Heavy Marine Lube	>100 >100	>1.8 >1.6	
Lago Medio	100 100 100 >100	9.8 9.8 9.8 >9.8	
Atkinson *	>100 >100	>2.0 >2.0	
Bunker C. Light	>100 >100	>2.3 >2.3	

* 24 hour data, not 48 hour

Table 4.

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	19.4 (10-32)	10.9 (5.6-17.9)	0.06 (0.03-0.1)
	18 (10-32)	10.1 (5.6-17.9)	0.05 (0.03-0.1)
	13.4 (10-18)	7.5 (5.6-10.1)	0.04 (0.03-0.05)
	13.4 (10-18)	7.5 (5.6-10.1)	0.04 (0.03-0.05)
Leaded Gasoline	<3.2	<5.4	<7.7
	<3.2	<5.4	<7.7
	3.2 (1.8-5.6)	5.4 (3.0-9.5)	7.7 (4.3-13.4)
	3.0 (1.8-5.6)	5.1 (3.0-9.5)	7.2 (4.3-13.4)
Unleaded Gasoline	1.3 (1-1.8)	4.0 (3.1-5.5)	1.5 (1.1-2.0)
	1.9 (1-3.2)	5.8 (3.1-9.8)	2.1 (1.1-3.6)
Diesel	16.7 (10-32)	6.5 (3.9-12.5)	0.5 (0.3-0.9)
	32 (18-56)	12.5 (7.0-21.9)	0.9 (0.5-1.6)
Sable Island Condensate	3.2 (1.8-5.6)	0.46 (0.3-0.8)	2.4 (1.4-4.3)
	3.8 (1.8-5.6)	0.55 (0.3-0.8)	2.9 (1.4-4.3)
Auto Lube (New)	>100	>0.99	>0.2
	>100	>2.0	>0.2
Auto Lube (Used)	>100	>18.6	>0.6
	>100	>18.6	>0.6
Bent Horn	25.5 (18-32)	1.6 (1.1-2.0)	1.9 (1.4-2.4)
	26.7 (18-56)	1.7 (1.1-3.6)	2.0 (1.4-4.3)
Venture Condensate	4.2 (3.2-5.6)	0.8 (0.6-1.1)	
	4.2 (3.2-5.6)	0.8 (0.6-1.1)	

Table 4. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Synthetic	12.0 (5.6-18)	0.27 (0.13-0.41)	3.6 (1.7-5.4)
	12.6 (10-18)	0.28 (0.23-0.41)	3.8 (3.0-5.4)
	14.3 (10-18)	0.32 (0.23-0.41)	4.3 (3.0-5.4)
	14.3 (10-18)	0.32 (0.23-0.41)	4.3 (3.0-5.4)
Western Sweet Blend	8.3 (5.6-18)	1.3 (0.9-2.9)	2.6 (1.7-5.6)
	9.3 (5.6-18)	1.5 (0.9-2.9)	2.9 (1.7-5.6)
Transmountain	13.4 (10-18)	1.1 (0.8-1.4)	2.1 (1.6-2.8)
	13.4 (10-18)	1.1 (0.8-1.4)	2.1 (1.6-2.8)
Norman Wells	21.6 (10-32)	3.0 (1.4-4.4)	2.4 (1.1-3.6)
	21.6 (10-32)	3.0(1.4-4.4)	2.4 (1.1-3.6)
Hibernia	13.4 (10-18)	1.1 (0.8-1.5)	3.1 (2.3-4.2)
	13.4 (10-18)	1.1 (0.8-1.5)	3.1 (2.3-4.2)
Amauligak	25.5 (18-32)	2.3 (1.6-2.9)	2.4 (1.7-3.1)
	26.7 (18-56)	2.4 (1.6-5.1)	2.6 (1.7-5.4)
Prudhoe Bay	13.4 (10-18)	-	3.4 (2.6-4.6)
	13.4 (10-18)	-	3.4 (2.6-4.6)
Tarsuit	83.3 (>56)	6.8 (>4.6)	1.7 (>1.1)
	86.3 (>56)	7.1 (>4.6)	1.7 (>1.1)
Venezuelan BCF-22	24.0 (18-32)	2.5 (1.9-3.3)	
	24.0 (18-32)	2.5 (1.9-3.3)	

Table 4 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 4 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Heavy Marine Lube	>100 >100	>2.2 >2.6	>0.8 >0.8
Lago Medio	29.8 (18-56) 26.7 (18-56)	3.6 (2.2-6.8) 3.2 (2.2-6.8)	2.5 (1.5-4.7) 2.2 (1.5-4.7)
Atkinson	24 (18-32) 26.7 (18-56)	0.54 (0.41-0.7) 0.61 (0.41-1.3)	0.74 (0.6-1.0) 0.83 (0.6-1.7)
Bunker C. Light	>100 >100	>4.5 >4.5	>0.4 >0.4

Table 5.

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	2.7 (0-6.3)	1.5 (0-3.5)	0.01 (0-0.02)
	2.1 (0-5.2)	1.2 (0-2.9)	0.006 (0-0.02)
	3.4 (1.8-5.6)	1.9 (1.0-3.1)	0.010 (0.005-0.02)
	3.8 (1.8-5.6)	2.1 (1.0-3.1)	0.011 (0.005-0.02)
Leaded Gasoline	<3.2	<5.4	<7.7
	3.4 (<56)	5.7 (<94.6)	8.2 (<134.4)
	4.2 (3.2-5.6)	7.1 (5.4-9.5)	10.1 (7.7-13.4)
	4.2 (3.2-5.6)	7.1 (5.4-9.5)	10.1 (7.7-13.4)
Unleaded Gasoline	1.3 (1-1.8)	4.0 (3.1-5.5)	1.5 (1.1-2.0)
	2.1 (1-3.2)	6.4 (3.1-9.8)	2.4 (1.1-3.6)
Diesel	7.5 (5.6-10)	2.9 (2.2-3.9)	0.21 (0.16-0.28)
	12.7 (8.5-17.0)	5.0 (3.3-6.6)	0.36 (0.24-0.48)
Sable Island Condensate	<1.8	<0.26	<1.4
	4.2 (3.2-5.6)	0.60 (0.5-.8)	3.2 (2.4-4.3)
	2.8 (1.8-5.6)	0.40 (0.3-.80)	2.1 (1.4-4.3)
Auto Lube (New)	15.0 (10-56)	0.15 (0.1-0.55)	0.03 (0.02-0.11)
	24 (18-32)	0.24 (0.18-0.32)	0.05 (0.04-0.06)
	16.7 (10-32)	0.34 (0.2-0.6)	0.03 (0.02-0.06)
	15.7 (10-32)	0.32 (0.2-0.6)	0.03 (0.02-0.06)
Auto Lube (Used)	25.5 (18-32)	4.8 (3.4-6.0)	0.15 (0.11-0.19)
	24 (18-32)	4.5 (3.4-6.0)	0.14 (0.11-0.19)
Bent Horn	18 (10-32)	1.1 (0.64-2.0)	1.4 (0.76-2.4)
	15.7 (10-32)	1.0 (0.64-2.0)	1.2 (0.76-2.4)

Table 5. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Venture Condensate	4.2 (3.2-5.6) 4.2 (3.2-5.6)	0.8 (0.6-1.1) 0.8 (0.6-1.1)	
Synthetic	8.3 (5.6-18) 7.7 (6.6-8.9) 13.4 (6.7-20.2) 12.0 (5.6-18)	0.19 (0.13-0.41) 0.17 (0.15-0.20) 0.30 (0.15-0.46) 0.27 (0.13-.41)	2.5 (1.7-5.4) 2.3 (2.0-2.7) 4.0 (2.0-6.0) 3.6 (1.7-5.4)
Western Sweet Blend	6.9 (0-14.5) 7.3 (6.1-8.6)	1.1 (0-2.3) 1.2 (1.0-1.4)	2.2 (0 - 4.5) 2.3 (1.9-2.7)
Transmountain	14.3 (10-18) 13.4 (10-18)	1.1 (0.79-1.4) 1.1 (0.79-1.4)	2.2 (1.6-2.8) 2.1 (1.6-2.8)
Norman Wells	14.3 (10-32) 14.3 (10-32) 13.4 (11.1-15.7)	2.0 (1.4-4.4) 2.0 (1.4-4.4) 1.3 (1.1-1.5)	1.6 (1.1-3.6) 1.6 (1.1-3.6) 1.5 (1.2-1.7)
Hibernia	13.4 (10-18) 12.6 (10-18)	1.1 (0.83-1.5) 1.0 (0.83-1.5)	3.1 (2.3-4.2) 2.9 (2.3-4.2)
Amauligak	19.3 (13.6-25.1) 16.7 (10-32)	1.7 (1.2-2.3) 1.5 (0.9-2.9)	1.9 (1.3-2.4) 1.6 (0.96-3.1)
Prudhoe Bay	13.4 (10-18) 13.4 (10-18)	- -	3.4 (2.6-4.6) 3.4 (2.6-4.6)
Tarsuit	42.3 (35.4-49.2) 42.3 (35.4-49.2)	3.5 (2.9-4.0) 3.5 (2.9-4.0)	0.85 (0.71-0.98) 0.85 (0.71-0.98)

Table 5 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour EC50 (immobilization). 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Venezuelan BCF-22	13.4 (10-18) 21.6 (10-32)	1.4 (1.0-1.9) 2.2 (1.0-3.3)	
Heavy Marine Lube	75.8 (27.6-123.9) 24 (18-100) 37.9 (29.4-46.4)	1.7 (0.6-2.7) 0.6 (0.5-2.6) 1.0 (0.7-1.2)	0.61 (0.22-0.99) 0.19 (0.14-0.80) 0.30 (0.24-0.37)
Lago Medio	26.6 (18.8-34.4) 26.6 (18.8-34.4)	3.2 (2.3-4.2) 3.2 (2.3-4.2)	2.2 (1.6-2.9) 2.2 (1.6-2.9)
Atkinson	26.7 (18-56) 26.7 (18-56)	0.61 (0.41-1.3) 0.61 (0.41-1.3)	0.83 (0.56-1.7) 0.83 (0.56-1.7)
Bunker C. Light	87.6 (>56) 100	3.9 (>2.5) 4.5	0.35 (>0.22) 0.40

Table 6.

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour LC50. 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Furnace Fuel	2.9 (0-8.2)	1.6 (0-4.6)	0.009 (0-0.02)
	3.0 (0-10.9)	1.7 (0-6.1)	0.009 (0-0.03)
	3.6 (1.8-5.6)	2.0 (1.0-3.1)	0.011 (0.005-0.02)
	4.4 (2.2-6.6)	2.5 (1.2-3.7)	0.013 (0.007-0.02)
Leaded Gasoline	4.5 (3.2-32)	7.6 (5.4-54)	10.8 (7.7-76.8)
	15.1 (9.8-20.3)	25.5 (16.6-34.3)	36.2 (23.5-48.7)
	6.9 (4.0-9.9)	11.7 (6.8-16.7)	16.6 (9.6-23.8)
	6.0 (2.6-9.4)	10.1 (4.4-15.9)	14.4 (6.2-22.6)
Unleaded Gasoline	13.5 (6.9-20.0)	41.4 (21.2-61.3)	15.1 (7.7-22.4)
	12.0 (4.1-19.9)	36.8 (12.6-61.0)	13.4 (4.6-22.3)
Diesel	18.2 (6.7-29.8)	7.1 (2.6-11.6)	0.51 (0.19-0.83)
	18.7 (14.1-23.3)	7.3 (5.5-9.1)	0.52 (0.39-0.65)
Sable Island Condensate	23.7 (15.5-31.8)	3.4 (2.2-4.6)	18.0 (11.8-24.2)
	23.4 (17.9-28.9)	3.4 (2.6-4.2)	17.8 (13.6-22.0)
	23.9 (18.2-29.6)	3.4 (2.6-4.3)	18.2 (13.8-22.5)
Auto Lube (New)	22.7 (13.7-31.7)	0.22 (0.14-0.31)	0.05 (0.03-0.06)
	24 (18-32)	0.24 (0.18-0.32)	0.05 (0.04-0.06)
	22.7 (17.9-27.5)	0.5 (0.4-0.6)	0.05 (0.04-0.06)
	28.8 (20.4-37.2)	0.6 (0.4-0.8)	0.06 (0.04-0.07)
Auto Lube (Used)	28.1 (18-56)	5.2 (3.4-10.4)	0.17 (0.11-0.34)
	24 (18-32)	4.5 (3.4-6.0)	0.14 (0.11-0.19)
Bent Horn	25.5 (18-32)	1.6 (1.1-2.0)	1.9 (1.4-2.4)
	29.7 (18-56)	1.9 (1.1-3.6)	2.3 (1.4-4.3)
Venture Condensate	29.7 (18-56)	5.8 (3.5-11.0)	
	29.7 (18-56)	5.8 (3.5-11.0)	

Table 6. (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour LC50. 95% confidence limits inn brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Synthetic	29.8 (18-100) 29.8 (18-100) 45.8 (18-100) 45.8 (18-100)	0.67 (0.41-2.3) 0.67 (0.41-2.3) 1.0 (0.41-2.3) 1.0 (0.41-2.3)	8.9 (5.4-29.9) 8.9 (5.4-29.9) 13.7 (5.4-29.9) 13.7 (5.4-29.9)
Western Sweet Blend	40.1 (31.6-48.6) 38.2 (18-56)	6.5 (5.1-7.8) 6.2 (2.9-9.0)	12.5 (9.9-15.2) 11.9 (5.6-17.5)
Transmountain	56 (32-100) 52.2 (32-100)	4.4 (2.5-7.9) 4.1 (2.5-7.9)	8.7 (5.0-15.5) 8.1 (5.0-15.5)
Norman Wells	59.8 (29.2-90.3) 49.3 (32-100) 62.3 (47.3-77.3)	8.3 (4.0-12.5) 6.8 (4.4-13.9) 6.0 (4.6-7.5)	6.6 (3.2-10.0) 5.5 (3.6-11.1) 6.9 (5.3-8.6)
Hibernia	63.5 (48.1-78.9) 68.7 (45.4-92.0)	5.3 (4.0-6.6) 5.7 (3.8-7.7)	14.8 (11.2-18.4) 16.0 (10.6-21.4)
Amauligak	72.5 (45.5-99.6) Not Calculable	6.6 (4.1-9.0) Not Calculable	7.0 (4.4-9.6) Not Calculable
Prudhoe Bay	60.3 (47.0-73.6) 92.4 (31.7-153.0)	- -	15.4 (12.0-18.8) 23.6 (8.1-39.0)
Tarsuit	74.8 (56-100) 79.1 (56-100)	6.1 (4.6-8.2) 6.5 (4.6-8.2)	1.5 (1.1-2.0) 1.6 (1.1-2.0)
Venezuelan BCF-22	84.6 (37.3-131.8) 70.4 (56-100)	8.7 (3.9-13.6) 7.3 (5.8-10.3)	

Table 6 (cont'd)

Acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna: 48 hour LC50. 95% confidence limits in brackets

OIL	NOMINAL AS % WSF	MEASURED BY FLUORESCENCE SPECTROSCOPY (mg/L)	MEASURED BY PURGE AND TRAP GC (mg/L)
Heavy Marine Lube	83.1 (39.1-127.1) >100	2.1 (1.0-3.2) >2.6	0.66 (0.31-1.02) >0.80
Lago Medio	>100 >100	>12.1 >12.1	>8.4 >8.4
Atkinson	>100 100	>2.3 2.3	>3.1 3.1
Bunker C. Light	>100 >100	>4.5 >4.5	>0.4 >0.4

Table 7.

Acute toxicity of water soluble fractions of crude and refined oils to *Artemia*. Data from all valid repicates combined.

OIL	48 HR EC50 NOMINAL (% WSF)	48 HR EC50 (MEASURED BY FLUORESCENCE IN MG/L)	48 HR LC50 NOMINAL (% WSF)	48 HR LC50 (MEASURED BY FLUORESCENCE IN MG/L)
Furnace Fuel	16.4 (10.7-22.0)	8.35 (5.45-11.21)	21.9 (16.5-27.3)	11.16 (8.41-13.91)
Leaded Gasoline	14.5 (9.8-19.2)	19.2 (13.0-25.4)	16.1 (10.3-22.0)	21.3 (13.6-29.1)
Unleaded Gasoline	9.6 (7.3-11.8)	25.1 (19.1-30.8)	19.7 (10.9-28.4)	51.4 (28.4-74.1)
Diesel	35.9 (29.0-42.7)	21.7 (17.5-25.8)	39.2 (30.6-47.8)	23.7 (18.5-28.9)
Sable Island Condensate	16.2 (13.0-19.3)	1.94 (1.55-2.31)	21.6 (17.3-25.9)	2.58 (2.07-3.09)
Auto Lube (New)	5.0 (0-105.3)	0.08 (0-1.51)	30.8 (6.6-55.0)	0.44 (0.1-0.79)
Auto Lube (Used)	>100	>12.8	>100	>12.8
Bent Horn	63.5 (24.3-102.6)	3.39 (1.3-5.48)	84.0 (25.6-142.4)	4.49 (1.37- 7.61)
Venture Condensate	22.6 (18.0-32.0)	3.72 (2.96-5.26)	26.3 (21.5-31.0)	4.33 (3.54-5.1)
Synthetic Crude Oil	28.3 (11.3-45.3)	1.4 (0.56-2.25)	37.8 (20.7-54.9)	1.88 (1.03-2.72)
Western Sweet Blend *	59.8 (41.7-78.0)	8.17 (5.7-10.7)	77.2 (54.4-99.9)	10.6 (7.44-13.65)
Transmountain *	64.7 (32.0-97.3)	3.61 (1.78-5.41)	>100	>5.56
Norman Wells	65.4 (56.0-100.0)	5.7 (4.88-8.71)	63.5 (34.7-92.4)	5.53 (3.03-8.05)
Hibernia	59.6 (42.0-77.3)	6.34 (4.47-8.22)	72.6 (44.0-101.2)	7.73 (4.68- 10.76)
Amauligak *	97.9 (> 56)	6.41 (> 3.67)	>100	>6.54
Prudhoe Bay	42.1 (19.2-65.0)	3.61 (1.65-5.57)	50.6 (16.1-85.1)	4.34 (1.38-7.3)
Tarsuit *	>100	> 7.2	>100	>7.2
Venezuelan BCF-22	42.3 (32.0-56.0)	4.06 (3.07-5.37)	42.3 (32.0-56.0)	4.06 (3.07-5.37)
Heavy Marine Lube	>100	> 1.66	>100	>1.66
Lago Medio	88.6 (> 56.0)	8.68 (> 5.49)	100 (> 56.0)	9.79 (> 5.49)
Atkinson *	>100	>2.03	>100	> 2.03
Bunker C. Light	>100	>2.29	>100	> 2.29

* = Test Duration 24 hours

Table 8.

Acute toxicity of water soluble fractions of crude and refined oils to *Daphnia magna*. Data from all valid repicates combined.

OIL	48 HR EC50 NOMINAL (%WSF)	48 HR EC50 (MEASURED BY FLUORESCENCE IN MG/L)	48 HR LC50 NOMINAL (% WSF)	48 HR LC50 (MEASURED BY FLUORESCENCE IN MG/L)
Furnace Fuel	3.4 (2.9-4.0)	1.9 (1.63-2.24)	3.9 (1.6-6.2)	2.18 (0.09-3.47)
Leaded Gasoline	3.7 (3.2-5.6)	6.25 (5.41-9.46)	8.0 (6.3-9.6)	13.5 (10.7-16.2)
Unleaded Gasoline	1.6 (1.0-3.2)	4.91 (3.07-9.81)	16.4 (8.5-24.3)	50.3 (26.1-74.5)
Diesel	10.4 (8.5-12.2)	4.07 (3.33-4.77)	18.3 (15.3-21.4)	7.16 (5.98-8.37)
Sable Island Condensate	2.8 (2.3-4.3)	0.41 (0.33-0.49)	23.7 (18.8-28.6)	3.41 (2.71-4.11)
Auto Lube (New)	19.3 (16.4-22.2)	0.3 (0.25-0.34)	25.1 (21.1-29.1)	0.38 (0.32-0.44)
Auto Lube (Used)	24.9 (18.0-32.0)	4.65 (3.36-5.97)	26.1 (18.0-32.0)	4.87 (3.36-5.97)
Bent Horn	16.7 (10.0-32.0)	1.07 (0.64-2.04)	27.4 (18.0-32.0)	1.75 (1.15-2.04)
Venture Condensate	4.2 (3.2-5.6)	0.83 (0.63-1.1)	29.8 (18.0-56.0)	5.84 (3.53-10.97)
Synthetic Crude Oil	10.1 (9.1-11.1)	0.23 (0.21-0.25)	36.8 (18.0-100.0)	0.84 (0.41-2.26)
Western Sweet Blend	6.9 (5.8-8.0)	1.12 (0.94-1.29)	38.9 (33.2-44.6)	6.28 (5.36-7.2)
Transmountain	13.9 (10.0-18.0)	1.1 (0.79-1.43)	54.0 (32.0-100.0)	4.27 (2.53-7.9)
Norman Wells	14.1 (12.6-15.7)	1.66 (1.49-1.84)	58.0 (49.7-66.3)	6.84 (5.86-7.81)
Hibernia	12.9 (10.0-18.0)	1.08 (0.83-1.5)	65.9 (52.6-79.3)	5.49 (4.38-6.6)
Amauligak	18.3 (13.9-22.7)	1.66 (1.26-2.05)	74.5 (51.9-97.1)	6.73 (4.69-8.77)
Prudhoe Bay	13.4 (10.0-18.0)	-	72.5 (53.4-91.7)	-
Tarsuit	42.3 (37.4-47.2)	3.47 (3.07-3.87)	77.6 (56.0-100.0)	6.37 (4.6-8.2)
Venezuelan BCF-22	16.5 (10.0-32.0)	1.72 (1.04-3.34)	77.2 (54.5-99.9)	8.06 (5.69-10.42)
Heavy Marine Lube	38.4 (29.1-47.6)	0.92 (0.7-1.4)	>100%	>2.38
Lago Medio	26.6 (21.8-31.5)	3.22 (2.64-3.82)	>100%	> 12.1
Atkinson	26.8 (18.0-32.0)	0.61 (0.41-0.73)	>100%	> 2.27
Bunker C. Light	93.0 (>56.0)	4.14 (>2.5)	>100%	> 4.45

Table 9 (a) Ranking of acute toxicity of water soluble fractions of crude and refined oils to Artemia based on nominal concentrations as % of WSF Listed by oil.

OIL	RANK (1 = most toxic)		
	4 HR. EC50	48 HR. EC50	48 HR. LC50
Unleaded Gasoline	1	2	2
Leaded Gasoline	2	3	1
Sable Is. Condensate	3	4	3
Venture Condensate	4	6	5
Western Sweet	6	11	13
Synthetic	11	7	7
Hibernia	12	11	12
Prudhoe Bay	12	9	10
Transmountain	9	14	16
Furnace Fuel	4	5	3
Norman Wells	8	14	11
Venezuelan BCF-22	7	9	9
Diesel	10	8	8
Atkinson	12	18	16
Bent Horn	12	13	14
Amauligak	12	17	16
Lago Medio	12	16	15
Tarsuit	12	18	16
Bunker C-Light	12	18	16
Auto Lube (New)	12	1	6
Auto Lube (Used)	12	18	16
Heavy Marine Lube	12	18	16

Table 9 (b) Ranking of acute toxicity of water soluble fractions of crude and refined oils to Artemia based on nominal concentrations as % of WSF Listed by rank.

Rank (1 = most toxic)	OIL 4 hour EC50	48 hour EC50	48 hour LC50
1	Unleaded gasoline	Auto lube (new)	Leaded gasoline
2	Leaded gasoline	Unleaded gasoline	Unleaded gasoline
3	Sable Is. Condensate	Leaded gasoline	Furnace Fuel, Sable Island Condensate
4	Venture Condensate, Furnace Fuel	Sable Is. Condensate	-
5	-	Furnace Fuel	Venture Condensate
6	Western Sweet	Venture Condensate	Auto Lube (New)
7	Venezuelan BCF-22	Synthetic	Synthetic
8	Norman Wells	Diesel	Diesel
9	Transmountain	Venezuelan BCF-22	Venezuelan BCF-22
10	Diesel	Prudhoe Bay	Prudhoe Bay
11	Synthetic	Western Sweet, Hibernia	Norman Wells
12	Atkinson, Bent Horn, Amauligak, Lago Medio, Tarsuit, Bunker C-Light, Auto Lube (used), Auto Lube (new), Heavy Marine Lube, Hibernia, Prudhoe Bay	-	Hibernia
13	-	Bent Horne	Western Sweet
14	-	Transmountain, Norman Wells	Bent Horne
15	-	-	Lago Medio

Table 9 (b) (cont'd) Ranking of acute toxicity of water soluble fractions of crude and refined oils to Artemia based on nominal concentrations as % of WSF
Listed by rank.

Rank (1 = most toxic)	OIL 4 hour EC50	48 hour EC50	48 hour LC50
16	-	Lago Medio	Transmountain, Atkinson, Amauligak, Tarsuit, Bunker C - Light, Auto Lube (used), Heavy Marine Lube
17	-	Amauligak	-
18	-	Heavy Marine Lube, Bunker C - Light, Atkinson, Auto Lube Used, Tarsuit,	-

Table 10 (a) Ranking of the acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna based on nominal concentrations as % of WSF Listed by oil.

OIL	RANK (1 = most toxic) 4 HR. EC50	48 HR. EC50	48 HR. LC50
Unleaded Gasoline	1	1	3
Leaded Gasoline	2	4	2
Sable Is. Condensate	3	2	5
Venture Condensate	4	4	9
Western Sweet	5	6	11
Synthetic	6	7	10
Hibernia	7	9	14
Prudhoe Bay	7	10	15
Transmountain	7	11	12
Furnace Fuel	10	2	1
Norman Wells	11	11	13
Venezuelan BCF-22	12	13	17
Diesel	13	7	4
Atkinson	14	18	19
Bent Horn	15	13	8
Amauligak	15	15	16
Lago Medio	17	18	19
Tarsuit	18	21	18
Bunker C-Light	19	22	19
Auto Lube (New)	19	16	6
Auto Lube (Used)	19	17	7
Heavy Marine Lube	19	20	19

Table 10 (b) Ranking of acute toxicity of water soluble fractions of crude and refined oils to Daphnia magna based on nominal concentrations as % of WSF
Listed by rank.

Rank (1 = most toxic)	OIL 4 hour EC50	48 hour EC50	48 hour LC50
1	Unleaded gasoline	Unleaded gasoline	Furnace fuel
2	Leaded gasoline	Sable Island Condensate, Furnace fuel	Leaded gasoline
3	Sable Island Condensate	-	Unleaded gasoline
4	Venture Condensate	Leaded gas, Venture Condensate	Diesel
5	Western Sweet	-	Sable Is. Condensate
6	Synthetic	Western Sweet	Auto Lube (new)
7	Hibernia, Prudhoe Bay, Transmountain	Diesel, Synthetic	Auto Lube (used)
8	-	-	Bent Horn
9	-	Hibernia	Venture Condensate
10	Furnace fuel	Prudhoe Bay	Synthetic
11	Norman Wells	Transmountain, Norman Wells	Western Sweet
12	Venezuelan BCF-22	-	Transmountain
13	Diesel	Bent Horn, Venezuelan BCF-22	Norman Wells
14	Atkinson	-	Hibernia
15	Bent Horn, Amauligak	Amauligak	Prudhoe Bay
16	-	Auto Lube (New)	Amauligak
17	Lago Medio	Auto Lube (used)	Venezuelan BCF-22
18	Tarsuit	Lago Medio, Atkinson	Tarsuit
19	Bunker C, Heavy Marine Lube, Auto Lube (New), Auto Lube (used)	-	Heavy Marine Lube, Atkinson, Lago Medio, Bunker C - Light

Table 10 (b) (cont'd) Ranking of acute toxicity of water soluble fractions of crude and refined oils to *Daphnia magna* based on nominal concentrations as % of WSF
Listed by rank.

Rank (1 = most toxic)	4 hour EC50	OIL 48 hour EC50	48 hour LC50
20	-	Heavy Marine Lube	-
21	-	Tarsuit	-
22	-	Bunker C - Light	-

Table 11. Acute toxicity of water soluble fractions of hydrocarbons to Artemis (brine shrimp)

Hydrocarbon	48 HR. EC50 (Immobilization) Nominal (%WSF)	48 HR. EC50 (Immobilization) Measured by Fluorescence Spectroscopy (mg/l)	48 HR. LC50 Nominal (%WSF)	48 HR. LC50 Measured by Fluorescence Spectroscopy (mg/l)
Benzene	6.72 (<10) 3.97 (3.2-5.6)	98.8 (<147) 58.4 (47.0-82.3)	6.65 (4.86-8.44) 9.44 (6.16-12.72)	97.8 (71.5-124) 139 (90.6-187)
Toluene*	6.72 (<10) 7.47 (4.34-10.6)	34.3 (<51) 38.1 (22.1-54.1)	10.5 (8.40-12.5) 12.0 (5.6-18)	53.6 (42.8-63.8) 61.2 (28.6-91.8)
Ethyl benzene	6.02 (3.30-8.73) 12.3 (7.96-16.7)	6.53 (3.58-9.46) 13.3 (8.63-18.1)	8.10 (3.61-12.60) 12.3 (7.96-16.7)	8.78 (3.91-13.7) 13.3 (8.63-18.1)
p-xylene*	16.7 (10-32) 13.4 (10-18)	20.6 (12.3-39.4) 16.5 (12.3-22.1)	22.6 (18-32) 22.6 (18-32)	27.8 (22.1-39.4) 27.8 (22.1-39.4)
o-xylene	8.41 (5.54-11.3) 7.08 (5.60-10.0)	12.7 (8.37-17.1) 10.7 (8.46-15.1)	18.0 (10-32) 14.8 (8.89-20.6)	27.1 (15.1-48.3) 22.4 (13.4-31.1)
m-xylene	7.90 (6.05-9.74) 10.1 (6.61-13.5) 7.48 (4.62-10.1) 6.01 (4.07-7.95)	8.54 (6.54-10.5) 10.9 (7.14-14.6) 7.09 (4.44-9.70) 5.77 (3.91-7.64)	13.7 (9.37-18.0) 11.3 (7.80-14.9) 9.20 (5.52-12.9) 8.87 (5.51-12.2)	14.8 (10.1-19.4) 12.2 (8.43-16.1) 8.84 (5.30-12.4) 8.52 (5.29-11.7)
Cumene	16.6 (7.96-25.3) 16.7 (8.21-25.1)	7.4 (3.55-11.29) 7.5 (3.66-11.2)	16.6 (7.96-25.3) 18 (7.84-28.2)	7.4 (3.55-11.29) 8.0 (3.5-12.59)
Naphthalene	24.5 (11.2-37.8) 26.6 (15.7-37.6)	5.96 (2.73-9.19) 6.47 (3.82-9.14)	51.4 (18.6-84.2) 40.4 (26.9-54)	12.5 (4.52-20.5) 9.82 (6.54-13.1)

*Test duration for these toxicants was 24 hours.

Table 12. Acute toxicity of water soluble fractions of hydrocarbons to Daphnia magna.

Hydrocarbon	48 HR. EC50 (Immobilization)		48 HR. LC50	
	Nominal (%WSF)	Measured by Fluorescence Spectroscopy (mg/l)	Nominal (%WSF)	Measured by Fluorescence Spectroscopy (mg/l)
Benzene	1.34 (1.0-1.8)	22.0 (16.4-29.5)	5.87 (3.57-8.18)	96.2 (58.5-134.1)
	1.34 (1.0-1.8)	22.0 (16.4-29.5)	6.05 (4.62-7.48)	99.2 (75.7-122.6)
	0.59 (<1.0)	9.23 (<15.6)	4.92 (2.55-7.3)	76.9 (39.9-114.1)
	0.64 (<1.0)	10.0 (<15.6)	3.81 (2.46-5.16)	59.6 (38.5-80.7)
	0.75 (0.56-1.0)	11.73 (8.76-15.6)	10.02 (6.57-13.47)	156.6 (102.7-210.9)
	0.64 (0-1.0)	10.0 (0-15.6)	8.68 (6.54-10.8)	135.7 (102.2-168.8)
Toluene	1.26 (1-1.8)	6.88 (5.46-9.83)	15.8 (10-32)	86.3 (54.6-174.7)
	1.20 (0-1.8)	6.56 (0-9.83)	17.9 (10-32)	97.7 (54.6-174.7)
Ethyl benzene	2.16 (1.0-3.2)	2.97 (1.37-4.4)	13.4 (8.37-18.5)	18.4 (11.5-25.4)
	2.13 (1.8-3.2)	2.93 (2.47-4.4)	10.1 (7.68-12.5)	13.9 (10.6-17.2)
p-xylene	2.55 (1.8-3.2)	5.03 (3.55-6.31)	18.8 (10-32)	37.0 (19.7-63.0)
	2.4 (1.8-3.2)	4.73 (3.55-6.31)	16.0 (5.75-26.3)	31.5 (11.3-51.8)
	-	-	18.6 (11.6-25.5)	33.1 (20.7-45.4)
	-	-	15.7 (10-32)	28.0 (17.8-57.0)
o-xylene	<1.0	<1.39	12.4 (6.74-18)	17.2 (9.37-25.0)
	1.34 (1.0-1.8)	1.87 (1.39-2.51)	14.1 (3.78-24.4)	19.6 (5.26-33.9)
	1.0 (0.56-1.8)	1.39 (0.78-2.51)	11.3 (8.08-14.6)	15.7 (11.2-20.3)
m-xylene	3.2 (1.8-5.6)	5.00 (2.81-8.74)	35.7 (18-56)	55.7 (28.1-87.4)
	2.26 (1.8-3.2)	3.53 (2.81-5.00)	15.1 (3.06-27.2)	23.6 (4.78-42.44)
Cumene	7.48 (5.6-10.0)	10.6 (7.90-14.1)	24.3 (15.8-32.8)	34.3 (22.3-46.3)
	7.48 (5.6-10.0)	10.6 (7.90-14.1)	21.6 (14.9-28.3)	30.5 (21.0-39.9)
	7.48 (5.6-10.0)	10.6 (7.90-14.1)	14.4 (5.6-32)	20.3 (7.90-45.1)
	7.96 (5.6-10.0)	11.2 (7.90-14.1)	14.4 (5.6-32)	20.3 (7.90-45.1)
Naphthalene	4.70 (3.2-10.0)	1.60 (1.09-3.40)	36.1 (26.1-46.2)	12.3 (8.88-15.7)
	7.48 (5.6-10.0)	2.55 (1.91-3.40)	33.4 (23.2-43.6)	11.4 (7.89-14.8)

Table 13.

Acute toxicity of water soluble fractions of hydrocarbons to *Artemia*.
Data from all valid repicates combined.

HYDROCARBON	48 HR EC50 NOMINAL (%WSF)	48 HR EC50 (MEASURED BY FLUORESCENCE IN MG/L)	48 HR LC50 NOMINAL (% WSF)	48 HR LC50 (MEASURED BY FLUORESCENCE IN MG/L)
Benzene	4.6 (3.5-5.7)	67.7 (51.5-83.8)	7.8 (6.3-9.2)	114.7 (92.7-135.3)
Toluene *	6.9 (4.4-9.4)	35.2 (22.5-48)	11.0 (9.4-12.6)	56.2 (48-64.3)
Ethyl Benzene	8.5 (6.2-10.8)	9.2 (6.7-11.7)	10.1 (7.3-13.0)	11.0 (7.9-14.1)
P-Xylene *	15.0 (10.0-18.0)	18.4 (12.3-22.1)	22.5 (18.0-32.0)	27.6 (22.1-39.2)
O-Xylene	7.5 (5.5-9.4)	10.5 (7.7-13.1)	16.2 (10.5-21.9)	22.6 (14.7-30.6)
M-Xylene	7.0 (5.8-8.1)	7.2 (5.9-8.3)	10.0 (8.0-12.0)	10.2 (8.2-12.3)
Cumene	16.5 (10.6-22.4)	7.4 (4.7-10)	16.4 (12.4-20.4)	7.3 (5.53-9.1)
Naphthalene	25.5 (14.8-36.2)	6.2 (3.6-8.8)	45.1 (20.3-69.9)	11.0 (4.9-17.0)

* Test Duration 24 hours

Table 14.

Acute toxicity of water soluble fractions of hydrocarbons to Daphnia magna. Data from all valid replicates combined.

HYDROCARBON	48 HR EC50 NOMINAL (%WSF)	48 HR EC50 (MEASURED BY FLUORESCENCE IN MG/L)	48 HR LC50 NOMINAL (% WSF)	48 HR LC50 (MEASURED BY FLUORESCENCE IN MG/L)
Benzene	0.81 (0.7-0.92)	12.9 (11.1-14.6)	5.9 (5.0-6.9)	88.9 (79.4-109.6)
Toluene	1.2 (1.0-1.8)	6.6 (5.5-9.8)	16.6 (10.0-32.0)	90.7 (54.6-174.8)
Ethyl Benzene	2.1 (1.8-3.2)	2.9 (2.5-4.4)	11.5 (9.1-13.9)	15.8 (12.5-19.1)
P-Xylene	2.5 (1.8-3.2)	4.7 (3.4-6.0)	18.0 (10.0-32.0)	33.7 (18.7-59.9)
O-Xylene	1.1 (0.56-1.8)	1.5 (0.78-2.5)	12.1 (7.7-16.5)	16.8 (10.7-22.9)
M-Xylene	2.7 (2.2-3.2)	4.1 (3.4-4.9)	17.4 (13.2-21.6)	26.5 (20.1-32.9)
Cumene	7.7 (5.6-10.0)	10.8 (7.9-14.1)	17.9 (14.8-21.1)	25.2 (20.8-29.7)
Naphthalene	6.0 (3.2-10.0)	2.0 (1.1-3.4)	34.6 (27.7-41.1)	11.7 (9.4-14.0)

Table 15. Effects of changing test conditions on the results of the Daphnia magna toxicity test for WSFs of oils. Lago Medio crude oil used as the model test toxicant (Ruggedness testing). All results in % WSF (nominal concentration).

Test Conditions*	48 Hour EC50 (immobilization)	48 Hour LC50
Standard test	26.6 (18.8-34.4)	>100
	26.6 (18.8-34.4)	-
	42.3 (32-56)	>100
	42.3 (32-56)	>100
	44.9 (32-56)	>100
Animals fed (during test)	22.6 (12.6-32.6)	>100
	32.5 (21.4-43.6)	>100
Tested in darkness only	24 (18-32)	>100
	24 (18-32)	>100
Tested in closed container with large air space (20% of test solution volume)	90.8 (30->100)	>100
Tested in open test container (not capped)	>100	>100

*Standard test = as described in Section 2.3.2. Variables changed from this standard are documented in this column.

Table 16. Results of toxicity tests conducted on the reference toxicants dodecyl sodium sulphate (DSS) and potassium dichromate using Artemia (Brine shrimp)

Reference Toxicant	Test Date	24 HR. EC50 (immobilization) in mg/l		24 HR. LC50 in mg/l	
		Replicate 1	Replicate 2	Replicate 1	Replicate 2
DSS (Fisher Scientific; Lot: 726579)	8 Dec., 1986	< 10	< 10	< 10	< 10
	11 Dec., 1986	< 10	< 10	5.9 (1.8-9.9)	< 5.6
	15 Dec., 1986	5.0 (3.6-6.4)	3.5 (1.4-5.6)	4.7 (2.2-7.1)	4.2 (0.7-7.8)
DSS (Kodak; Lot: C157)	13 Jan., 1987	36.4 (18-56)	28.1 (18-56)	36.4 (18-56)	29.7 (18-56)
	23 Jan., 1987	29 (25-33.1)	27.9 (23.1-32.6)	30.9 (24-37.7)	27.9 (23.1-32.6)
DSS (Received from University of Toronto)*	23 Jan., 1987	25.5 (22.2-28.8)	23.6 (20-27.2)	28.5 (25.4-31.5)	26.5 (20.9-32.1)
Potassium dichromate (Fisher Scientific; Lot: 775173)	11 Dec., 1986	91 (47.2-135)	Not calculable	> 100	> 100
	16 Jan., 1987	126 (100-180)	112 (56-180)	134 (100-180)	134 (81.7-186)

* Received from: Mr. S. Abernathy, Institute for Environmental Studies, University of Toronto. This batch of DSS was originally used in an intercalibration exercise sponsored by the Artemia Reference Centre, State University of Ghent, Ghent, Belgium.

APPENDIX 1

Preparation of Dilution Water for Artemia and Daphnia Magna Toxicity Tests

1. Dilution water for Daphnia magna tests.

This water was used to prepare the WSFs of the test oils, as well as to culture the test animals and as dilution water in the toxicity tests. The preparation of this water is described in International Standard ISO 6341-1982(E) prepared by the International Organization for Standardization*, and it is summarized briefly below:

(a) Four stock solutions are prepared:
- 11.76 g $CaCl_2 \cdot 2H_2O$ dissolved and made up to 1 litre (l) with distilled deionized water
- 4.93 g $MgSO_4 \cdot 7H_2O$ is dissolved and made up to 1 litre in distilled deionized water
- 2.59 g $NaHCO_3$ is dissolved and made up to 1 litre in distilled deionized water
- 0.23 g KCl is dissolved and made up to 1 litre in distilled deionized water

(b) 500 ml of each stock solution is added to 18 litre distilled deionized water to give a final volume of 20 litres

(c) The dilution water is aerated for about 24 hours to saturate it with dissolved oxygen and to stabilize the pH. If necessary, adjust the pH to 7.8 $\pm$ 0.2 by adding sodium hydroxide solution or hydrochloric acid solution.

This water prepared as above has a pH of 7.8 $\pm$ 0.2, a hardness (as $CaCO_3$) of 250 $\pm$ 25 mg/l, a Ca/Mg ratio of close to 4:1, and a dissolved oxygen concentration above 80% saturation.

*Anonymous, 1982 (See References Cited).

Table 17. Results of toxicity tests conducted on the reference toxicant potassium dichromate. Results expressed as 24 hour EC50 (Immobility) to Daphnia magna (QA/QC tests).

Test Date	24h-EC(I)50 mg/L*	95% Confidence Interval
13 August 1986	0.82	0.59-1.06
14 August 1986	1.0	0.68-1.5
28 August 1986	1.03	0.9 -1.1
28 August 1986	1.0	0.93-1.1
1 September 1986	0.98	> 0.68
1 September 1986	0.9	0.6 -1.1
3 September 1986	1.0	0.9 -1.1
3 September 1986	1.0	0.8 -1.1
9 October 1986	0.8	0.7 -1.0
20 October 1986	1.3	1.2 -1.4
22 October 1986	0.92	0.81-1.4
17 November 1986	1.07	0.9 -1.2
5 December 1986	0.94	0.82-1.08
30 December 1986	1.3	1.2 -1.5
5 February 1987	1.34	1.0 -1.5
9 February 1987	1.05	0.87-1.2
12 February 1987	1.13	0.94-1.3
12 February 1987	1.13	0.99-1.3
3 March 1987	0.84	0.48-1.2
5 March 1987	1.4	1.3 -1.6

*Using the procedure in Anonymous (1982), the 24h-EC(I)50 should fall in the range 0.9-2.0 mg/L

2. Dilution water for Artemia tests.

700 grams of Instant Ocean brand seawater was added to 20 litres of distilled deionized water (35 g /litre). The mixture was stirred for 4-5 hours and then filtered through 1.2 um mixed cellulose nitrate and acetate millipore filters (47 mm diameter) into a Nalgene polypropylene carboy.

After filtration the water was gently aerated for approximately 24 hours at room temperature.

This water prepared above has a salinity of 30 0/00 $\pm$ 2, pH of 8.0 $\pm$ 2 and a dissolved oxygen concentration above 80% saturation, and was used to prepare the WSFs of the test oils, as well as to culture the test animals and as dilution water in the toxicity tests.

APPENDIX 2

Ranges of temperature, dissolved oxygen and pH measured on test solutions from *Artemia* and *Daphnia magna* toxicity tests

RANGES OF TEMPERATURE DISSOLVED OXYGEN AND PH VALUES MEASURED ON *ARTEMIA* TEST SOLUTIONS.

TEST OIL	TEMPERATURE (^{0}C)	DISSOLVED OXYGEN (mg/L)	PH
WESTERN SWEET BLEND	20-22	6.3-7.2	8.0-8.2
NORMAN WELLS	19.5-22	5.7-7.2	8.2-8.3
LAGO MEDIO	20-21	6.1-7.7	7.9-8.3
PRUDHOE BAY	22-23	6.2-7.4	8.0
TRANSMOUNTAIN	21-22.5	6.4-7.2	8.2
BENT HORN	20-21	6.5-7.1	8.2-8.4
AMAULIGAK	20-21	6.7-7.2	8.1-8.2
TARSUIT	20.5-22	6.9-7.1	8.0-8.3
ATKINSON	21-22.5	6.8-7.1	8.0-8.2
HIBERNIA	21.5-22	6.4-7.4	8.2
SABLE ISLAND CONDENSATE	20-22	6.8-7.2	8.3
SYNTHETIC	21-23	5.6-7.2	8.3
BUNKER C LIGHT	22-24	1.5-7.0	8.2
UNLEADED GASOLINE	20-21	4.9-7.5	8.4
LEADED GASOLINE	19-21	3.9-7.5	8.4
FURNACE FUEL	20-21.5	7.1-7.5	8.3-8.4
DIESEL	21-22	8.4-8.7	8.1-8.2
AUTO LUBE (NEW)	20-22	6.3-7.2	8.1-8.2
AUTO LUBE (USED)	20-22	5.7-8.4	7.9-8.4
HEAVY MARINE LUBE	21.5-24	5.8-7.1	8.1
VENEZUELAN BCF 22	22-23	3.0-7.4	7.9-8.1
VENTURE CONDENSATE	21-22.5	6.1-7.1	8.4
BENZENE	20-22	6.7-7.2	8.3
ETHYL BENZENE	23-24	7.0-7.4	8.1-8.2
p-XYLENE	21-22.5	7.1-7.2	8.1-8.2
o-XYLENE	19.5-22	6.9-7.1	8.3-8.4
m-XYLENE	21.5-23	7.0-8.5	8.0-8.3

RANGES OF TEMPERATURE, DISSOLVED OXYGEN, AND PH VALUES MEASURED ON *ARTEMIA* TEST SOLUTIONS (CONTINUED).

TEST OIL	TEMPERATURE (^{0}C)	DISSOLVED OXYGEN (mg/L)	PH
TOLUENE	20-22	6.9-7.1	8.2-8.3
CUMENE	19.5-22	7.0-7.1	8.3
NAPHTHALENE	20-22	7.0-7.2	8.4-8.5

RANGES OF TEMPERATURE DISSOLVED OXYGEN AND PH VALUES MEASURED ON *DAPHNIA MAGNA* TEST SOLUTIONS.

TEST OIL	TEMPERATURE (^{0}C)	DISSOLVED OXYGEN(mg/L)	PH
WESTERN SWEET BLEND	19.5-22	6.9-8.8	7.6-8.0
NORMAN WELLS	21-22.5	7.7-7.8	7.4-8.4
LAGO MEDIO	21-22.5	8.2-8.7	7.7-7.9
PRUDHOE BAY	19-22	6.-8.3	7.7-7.9
TRANSMOUNTAIN	20-22.5	7.4-9.0	7.3-7.7
BENT HORN	20-23	7.0-8.6	7.4-7.6
AMAULIGAK	22-23.5	7.6-8.3	7.9-8.1
TARSUIT	20-23	7.9-8.9	7.4-7.7
ATKINSON	21.5-23.5	7.8-8.9	7.3-7.8
HIBERNIA	19-22	7.7-8.8	7.4-7.6
SABLE ISLAND CONDENSATE	20-22	7.7-9.0	7.5-8.0
SYNTHETIC	21-23.5	7.0-8.7	7.7-8.2
BUNKER C LIGHT	21-22	6.1-9.2	7.6-7.9
UNLEADED GASOLINE	19-21.5	8.1-9.5	7.8-8.2
LEADED GASOLINE	20-21	8.0-9.6	7.6-8.0
FURNACE FUEL	19-23	8.3-9.5	7.7-8.1
DIESEL	18.5-20	6.9-7.4	8.1-8.4
AUTO LUBE (NEW)	19-23	7.9-8.9	7.1-7.6
AUTO LUBE (USED)	20-21	7.3-8.2	7.3-7.9
HEAVY MARINE LUBE	19-23.5	7.2-8.8	7.4-7.9
VENEZUELAN BCF 22	20-22	5.3-9.2	7.5-7.9
VENTURE CONDENSATE	21-22.5	6.0-9.2	7.5-7.8
BENZENE	20.5-23	7.9-9.0	7.8-8.1
ETHYL BENZENE	20-21.5	9.5-10	7.8-8.2
p-XYLENE	20.5-21	8.5-8.9	7.4-7.9
o-XYLENE	19.5-22	9.5-9.6	7.8-8.1
m-XYLENE	20-22	8.1-8.9	7.2-8.0

RANGES OF TEMPERATURE, DISSOLVED OXYGEN, AND PH VALUES MEASURED ON *DAPHNIA MAGNA* TEST SOLUTIONS (CONTINUED).

TEST OIL	TEMPERATURE (^{0}C)	DISSOLVED OXYGEN (mg/L)	PH
TOLUENE	20-21	8.4-8.8	7.7-7.9
CUMENE	19-23	7.2-8.6	7.5-7.9
NAPHTHALENE	22-23	8.0-9.5	7.8-8.2

APPENDIX 3

Results of analyses of toxicity test solutions for petroleum hydrocarbons by fluorescence spectroscopy

Appendix 3 (a)

Measurements of Petroleum Hydrocarbons by Fluorescence for Artemia test solutions. Corrected for control values.**

OIL	CONC (% WSF)	INITIAL measured value mg/L	FINAL measured value mg/L	EXCITATION (nm)	EMISSION (nm)
Western Sweet Blend	100	13.66	-*	270	300
	0	0	-		
Norman Wells	100	8.71	8.38	270	300
	0	0	-		
Lago Medio	100	9.79	9.73	270	300
	0	0	0		
Prudhoe Bay	100	8.57	9.08	270	300
	0	0	0		
Transmountain	100	5.56	5.56	270	300
	0	0	0		
Bent Horn	100	5.34	5.34	270	300
	0	0	0		
Amauligak	100	6.54	-	270	300
	0	0	-		
Tarsuit	100	7.2	7.2	270	300
	0	0	0		
Atkinson	100	2.03	-	270	300
	0	0	-		
Hibernia	100	10.63	10.63	270	300
	0	0	0		
Sable Island Condensate	100	11.93	11.60	270	300
	0	0	0		
Synthetic	100	5.35	4.72	270	305
	0	0	0		
	100	4.55	4.61		
	0	0	0		
Bunker C - Light	100	2.29	2.37	270	305
	0	0	0		

* - A dash means no measurement conducted.
** Control values usually less than 5% of oil WSF value.

Appendix 3 (a)

Measurements of Petroleum Hydrocarbons by Fluorescence for *Artemia* test solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Unleaded Gasoline	100	260.92	260.92	260	280
	0	0	0		
Leaded Gasoline	100	132.35	132.35	260	280
	0	0	0		
Furnace Fuel	100	50.92	50.92	270	300
	0	0	0		
Diesel	100	60.42	54.71	270	300
	0	0	0		
Auto Lube (new)	100	1.12	-*	270	300
	0	0	-		
	100	1.74	1.74	270	300
	0	0	0		
Auto Lube (used)	100	15.97	24.75	270	300
	0	0	0		
	100	9.69	-		
	0	0	-		
Heavy Marine Lube	100	1.77	1.32	270	300
	0	0	0		
	100	1.55	-		
	0	0			
Venezuelan BCF-22	100	9.58	8.82	270	300
	0	0	0		
Venture Condensate	100	16.44	16.44	270	300
	0	0	0		
Benzene	100	1470.59	1470.59	260	280
	0	0	0		
Ethyl Benzene	100	108.4	108.4	260	280
	0	0	0		
Toluene	100	510.42	-	260	280
	0	0	-		

* A dash means no measurement conducted

Appendix 3 (a)

Measurements of Petroleum Hydrocarbons by Fluorescence for *Artemia* test solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Cumene	100	44.63	44.43	280	300
	0	0	0		
P-xylene	100	122.52	124.03	260	280
	0	0	0		
M-xylene	100	108.40	108.40	260	280
	0	0	0		
	100	95.80	-*		
	0	0	-		
O-xylene	100	128.15	101.85	260	280
	0	0	0		
	100	151.26	-		
	0	0	-		
Naphthalene	100	24.33	23.19	290	320
	0	0	0		

* A dash means no measurement conducted.

Appendix 3 (b)

Measurements of Petroleum Hydrocarbons by Fluorescence for *Daphnia magna* Test Solutions. Corrected for control values**

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Western Sweet Blend	100	16.13	16.13	270	300
	32	6.02	5.88		
	10	1.98	2.05		
	0	0	0		
Norman Wells	100	13.86	-*	270	300
	32	4.09	3.06		
	10	1.33	1.13		
	0	0.	0		
	100	9.7	10.12	270	300
	32	3.06	3.06		
	10	-	-		
	0	0	0		
Lago Medio	100	12.10	10.59	270	300
	32	4.37	4.37		
	10	1.18	1.18		
	0	0	0		
Transmountain	100	7.90	7.90	270	300
	32	2.45	2.66		
	10	0.64	0.76		
	0	0	0		
Bent Horn	100	6.36	6.39	270	300
	32	1.59	1.98		
	10	0.5	0.50		
	0	0	0		
Amauligak	100	9.06	9.1	270	300
	32	2.61	2.83		
	10	0.76	0.87		
	0	0	0		

* A dash means no measurement conducted.
** Control values usually less than 5% of oil WSF values.

Appendix 3 (b)

Measurements of Petroleum Hydrocarbons by Fluorescence for Daphnia magna Test Solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Tarsuit	100	8.20	7.97	270	300
	32	2.92	1.51		
	10	0.94	0.72		
	0	0	0.02		
Atkinson	100	2.27	2.19	270	300
	32	0.07	0.57		
	10	-*	-		
	0	0	0		
Hibernia	100	8.32	9.99	270	300
	32	2.37	3.25		
	10	1.48	1.09		
	0	0	0		
Sable Island Condensate	100	14.37	14.58	270	300
	32	4.47	4.47		
	10	1.73	1.46		
	0	0	0		
Synthetic	100	2.26	2.26	270	305
	32	0.70	-		
	10	0.28	0.28		
	0	0	0		
Bunker C - Light	100	4.45	4.45	270	300
	32	1.93	1.60		
	10	0.35	0.24		
	0	0	0		
Unleaded Gasoline	100	306.55	320.17	260	280
	32	-	-		
	10	32.77	32.77		
	0	0	0		
Leaded Gasoline	100	168.91	187.82	260	280
	32	57.35	57.35		
	10	19.12	19.12		
	0	0	0		
	100	168.91	132.35		
	32	57.35	57.35		
	10	22.06	19.12		
	0	0	0		

* A dash means no measurement conducted.

Appendix 3 (b)

Measurements of Petroleum Hydrocarbons by Fluorescence for *Daphnia magna* Test Solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Furnace Fuel	100	55.97	55.46	270	300
	32	17.44	17.39		
	10	5.77	6.05		
	0	0	0		
	100	55.85	55.89		
	32	18.54	18.16		
	10	-*	-		
	0	0	0		
Diesel	100	39.08	38.19	270	300
	32	7.98	7.73		
	10	3.87	4.37		
	0	0	0		
Auto Lube (new)	100	0.99	0.72	270	300
	32	0.39	0.18		
	10	0.24	0.24		
	0	0	0		
	100	2.02	2.02		
	32	-	-		
	10	-	-		
	0	0	0		
Auto Lube (used)	100	18.64	19.25	270	300
	32	7.24	5.13		
	10	2.32	1.78		
	0	0	0		
Heavy Marine Lube	100	2.21	1.79	270	300
	32	0.76	0.42		
	10	0.34	0.17		
	0	0	0		
	100	2.55	-		
	32	1.03	1.03		
	10	0.34	0.17		
	0	0	0		
Venture Condensate	100	19.59	19.66	270	300
	32	6.33	6.40		
	10	2.2	1.76		
	0	0	-		

* A dash means no measurement conducted.

Appendix 3 (b)

Measurements of Petroleum Hydrocarbons by Fluorescence for Daphnia magna Test Solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Venezuelan BCF-22	100	10.43	8.32	270	300
	32	3.58	2.77		
	10	1.19	1.09		
	0	0	0		
Benzene	100	1638.66	1638.66		
	32	506.31	506.31		
	10	191.18	174.37		
	0	0	0		
	100	1563.03	1563.03	260	280
	32	521.01	521.01		
	10	159.66	159.66		
	0	0	0		
	100	1563.03	1563.03	260	280
	0	0	0		
Ethyl Benzene	100	137.39	137.39	260	280
	32	45.8	44.75		
	10	15.76	15.76		
	0	0	0		
Toluene	100	546.22	546.22	260	280
	32	171.43	159.66		
	10	54.62	50.42		
	0	0	0		
P-xylene	100	196.64	196.64		
	32	72.69	72.69		
	10	-*	-		
	0	0	0		
	100	177.73	175.21		
	32	54.20	-		
	10	18.17	-		
	0	0	0		
O-xylene	100	138.66	147.48	260	280
	32	46.64	46.64		
	10	19.22	19.22		
	0	0	0		
M-xylene	100	152.52	152.52	260	280
	32	-	-		
	10	-	-		
	0	0	0		

* A dash means no measurement conducted.

Appendix 3 (b)

Measurements of Petroleum Hydrocarbons by Fluorescence for *Daphnia magna* Test Solutions. Corrected for control values.

OIL	CONC (% WSF)	INITIAL measured value (mg/L)	FINAL measured value (mg/L)	EXCITATION (nm)	EMISSION (nm)
Cumene	100	140.55	140.55	280	300
	32	44.37	41.34		
	10	19.75	12.77		
	0	0	0		
Naphthalene	100	33.78	34.79	290	320
	32	10.38	10.92		
	10	3.38	3.38		
	0	0	0		